Constructing Price Indexes Across Space and Time: The Case of the European Union

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This paper considers the problem of how to construct and reconcile price indexes across space and time. Six methods for constructing price indexes on a panel are proposed along with five criteria for discriminating between them. Using these methods, spatial and temporal price indexes are computed for the 15 countries of the European Union (EU) over the period 1995-2000 using a panel data set constructed by merging, at a low level of aggregation, the EU's Harmonized Index of Consumer Prices (HICP) with a cross-section of OECD data. These panel price indexes are then used to test whether or not price levels and relative prices converged across the EU over this period. (*JEL* C43, E31, O47)

KEY WORDS: Price Index; Panel Data; Chaining; Spanning Tree; Temporal Consistency; Spatial Consistency; Temporal Fixity; Spatial Fixity; Temporal Displacement; Convergence

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1. Introduction

Comparing the purchasing power of currencies and price levels across countries and how they change over time is an issue of interest to national governments, firms and households, and international organizations such as the International Monetary Fund (IMF), World Bank and European Union (EU). To compare simultaneously price levels and changes in the price level requires the application of index number methods to a panel data set. This is an issue that has received very little attention in the index number literature, particularly in a consumer context. This is largely due to a lack of suitable data sets. The EU's Harmonized Index of Consumer Prices (HICP), for example, allows comparisons of inflation rates and by implication changes in the price level across EU countries. However, it cannot be used to compare price levels and the purchasing power of currencies across countries in a given year since it is constructed only from the consumer price index (CPI) data of each country. This means that the price level in all countries is normalized to 100 in the base year (1996). Individual countries, likewise, tend to focus their attention primarily on constructing temporal price indexes. Some countries compute regional CPIs. However, just as with the HICP, although this allows comparisons of changes in the price level across regions, it does not allow comparisons of the price level across regions at a particular point in time. Conversely, international organizations such as the OECD and World Bank make detailed cross-section comparisons across countries. Although the OECD makes such comparisons at 3 year intervals, the headings can differ significantly from one cross-section to the next and hence the cross-sections are not directly comparable.

One notable exception to this general rule is the Penn World Table (PWT). The PWT is a product of the International Comparison Program (ICP) which dates back to the 1960s and has at various times been funded by the United Nations, World Bank and OECD, and has been extensively used by economists to test for convergence in living standards across countries [see for example Barro and Sala-i-Martin (1992)]. The PWT provides price levels for 152 countries over the period 1950-1998 (see <http://pwt.econ.upenn.edu>). However, the PWT is constructed by splicing together at an aggregated level cross-section benchmarks with time-series data obtained from the individual countries [see Kravis, Heston and Summers (1982) and Summers and Heston

(1991)]. Hence, in the process of constructing it, Kravis, Heston and Summers did not have to address directly the issue of price index construction on a disaggregated panel data set, although they did have to confront the related problem of reconciling temporal and spatial price indexes which is also addressed in this paper.

The first objective of this paper is to develop a methodology of panel price indexes. Since panel comparisons combine temporal and spatial comparisons, this means that all the issues that arise in the temporal and spatial index number literatures are also relevant to panel comparisons.[1] For example, one of the key issues in the temporal literature is the debate over the relative merits of chained and fixed-base price indexes, and in the latter case the frequency with which the index should be rebased. In the spatial literature, a large number of alternative multilateral formulae have been proposed, and there is still widespread disagreement as to which formula is best [see Hill (1997)]. In addition, in a panel comparison a conflict exists between the temporal and spatial price indexes. Six different classes of methods for constructing price indexes on a panel data set are proposed. Methods from these classes are then compared using five criteria. The related issue of reconciling temporal and spatial price indexes is also considered. The same methods and criteria can be used to address this problem.

The second objective is to apply the panel index-number methodology to the European Union over the period 1995-2000. To do this it was first necessary to combine the EU's Harmonized Index of Consumer Prices (HICP) data set with OECD cross-section data to produce a panel data set that can be used to make both temporal and spatial comparisons. Price indexes for the 15 member countries of the EU are then constructed over the period 1995-2000, and the sensitivity of the results to the choice of panel method assessed. Price levels and relative prices are also compared across the EU to determine whether they are converging or diverging over time. We find evidence of convergence in price levels but divergence in relative prices. The paper concludes by discussing some of the implications of these findings.

[1]Here we use the terminology "spatial" to refer to comparisons across countries (or regions) at a particular point in time, and "temporal" to denote comparisons for a given country (or region) across different points in time.

2. Bilateral Comparisons

The set of time periods is indexed by $t = 1, \ldots, T$, the set of countries by $k = 1, \ldots, K$ and the set of commodity headings by $i = 1, \ldots, N$. The price and quantity data of commodity heading i for country k in period t are denoted, respectively, by p^i_{kt} and q^i_{kt}.

Let $P_{js,kt}$ denote a bilateral price index comparison between country j in time period s and country k in time period t. Four important bilateral formulae are Paasche, Laspeyres, Fisher, and Törnqvist.[2] These indexes are defined below:

$$\text{Paasche}: \quad P^P_{js,kt} = \frac{\sum_{i=1}^N p^i_{kt} q^i_{kt}}{\sum_{i=1}^N p^i_{js} q^i_{kt}}, \tag{1}$$

$$\text{Laspeyres}: \quad P^L_{js,kt} = \frac{\sum_{i=1}^N p^i_{kt} q^i_{js}}{\sum_{i=1}^N p^i_{js} q^i_{js}}, \tag{2}$$

$$\text{Fisher}: \quad P^F_{js,kt} = \sqrt{P^P_{js,kt} P^L_{js,kt}}, \tag{3}$$

$$\text{Törnqvist}: \quad P^T_{js,kt} = \prod_{i=1}^N \left(\frac{p^i_{kt}}{p^i_{js}} \right)^{\frac{s^i_{js} + s^i_{kt}}{2}} \quad \text{where} \quad s^i_{js} = \frac{p^i_{js} q^i_{js}}{\sum_{l=1}^N p^l_{js} q^l_{js}}. \tag{4}$$

Two main approaches have been used to choose between competing bilateral formulae. The axiomatic approach specifies axioms that a price index should satisfy, and then compares formulae on the basis of which axioms they pass and fail [see Eichhorn and Voeller (1976), and Balk (1995)]. This approach, however, was criticized by Afriat (1977) in that it provides answers without questions. The economic approach, by contrast, is firmly grounded in economic theory. The underlying concept, according to the economic approach, is the cost of living (COL) index defined as follows:

$$COL_{js,kt} = \frac{e(u, p_{kt})}{e(u, p_{js})},$$

where $e(u, p)$ is the minimum expenditure required to reach the utility level u, given prices p. There are three main problems with the economic approach. First, the COL index depends on the reference utility level (unless preferences are homothetic). Second, it assumes a representative consumer.[3] Third, the COL index is not directly observable.

[2] The history of these bilateral formulae is discussed in Diewert (1993).

[3] The COL can be generalized to groups [see Diewert (1984)].

When preferences are homothetic, the COL index is bounded from below by Paasche, and from above by Laspeyres. However, these bounds may still be quite far apart.

Here we briefly discuss three solutions to the problem of computing the COL index. The first solution [see Neary (1999)] is to estimate the demand system. Unfortunately, in many data sets this is not practicable, since the number of commodity headings often exceeds the number of country-time periods in the sample. The second solution, suggested by Dowrick and Quiggin (1997), is to assume homothetic preferences and tighten the bounds by taking account of indirect comparisons via other country-time periods. They use the geometric mean of these homothetic bounds, which they refer to as an Afriat index [see also Afriat (1967)]. The third solution is to appeal to utility maximization. Under this assumption, once a functional form has been specified for the expenditure function, the COL reduces to a function of observable prices and quantities. Diewert (1976) advocated using a price index which is exact for a flexible expenditure function (i.e., one that can approximate to the second order an arbitrary linearly homogeneous function). Diewert refers to such price indexes as *superlative*. Fisher and Törnqvist are superlative, while Paasche and Laspeyres are not.[4] Coincidentally, Fisher and Törnqvist are also the formulae that tend to emerge as best from the axiomatic approach.

A strong consensus has emerged in the index number literature that bilateral comparisons should be made using superlative index numbers [see Triplett (1996)].

3. Multilateral Comparisons

The problem with bilateral formulae in a multilateral context is that they are not transitive (except in degenerate cases where the weight attached to each commodity heading in the price index formula is the same for all countries). For example a direct comparison between country j in period s and country k in period t will yield a different answer than an indirect comparison via country m in time period u, i.e., $P_{js,kt} \neq P_{js,mu} \times P_{mu,kt}$. This is true even of superlative indexes. Transitivity is necessary to ensure internal consistency. Otherwise, more than one estimate of each bilateral comparison will be derivable from the price indexes.

[4]Fisher is exact for the homogeneous quadratic utility function, while Törnqvist is exact for the homogeneous translog utility function.

Let P_{js} and P_{kt} denote multilateral price indexes for country j in period s and country k in period t, respectively. Multilateral indexes, by construction, are transitive. Hence a bilateral comparison of prices made using a multilateral formula can be expressed as follows:

$$P_{js,kt} = \frac{P_{kt}}{P_{js}}. \tag{5}$$

The bilateral formulae discussed in the previous section, since they are not transitive, cannot be written in this way.

Graph Theory provides a useful framework for analyzing the underlying structure of multilateral price indexes. A graph consists of a collection of vertices linked by edges. In the context of spatial (temporal) comparisons, each vertex represents one of the countries (time periods) in the comparison, while each edge represents a bilateral comparison between a pair of countries (time periods). Three important graphs, depicted in Figure 1 for the case of 5 vertices, are the *star*, *complete* and *chain* graphs.

Insert Figure 1 Here

A large number of multilateral formulae have been proposed for making spatial comparisons in the index number literature [see for example Balk (1996), Hill (1997) and Diewert (1999) for surveys of this literature]. Many of these formulae can be described using graphs. At present, however, there is still no consensus as to which formula is the best.[5] Here we focus attention on three classes of multilateral formulae.

(i) Average-Price Methods

The first class compares each country with an artificially constructed average country. By implication, the underlying structure of such methods is a star graph with an artificial average country at the center of the star. Each bilateral comparison in the star is made using the Paasche price index formula, with the artificial country as the base. In the context of a spatial comparison (i.e., for a fixed value of t) the price index

[5] In contrast, attention in the literature on temporal comparisons has focused on two main methods, the so-called fixed-base method which uses the star graph and the chain method which uses the chain graph. A broad consensus has emerged in the temporal index-number literature that, at least for annual data, the chain graph should be used with the time periods linked chronologically and that Fisher or Törnqvist should be used to make the bilateral comparisons [see Boskin et al. (1996) and Hill (2001)].

of country k in time period t, P_{kt}, is calculated as follows:

$$P_{kt} = P^P_{Xt,kt} = \frac{\sum_{i=1}^N p^i_{kt} q^i_{kt}}{\sum_{i=1}^N p^i_{Xt} q^i_{kt}} \quad \text{for} \quad k = 1, \ldots, K, \tag{6}$$

where p^i_{Xt} denotes the price of commodity heading i in the artificially constructed average country in period t.[6,7] The most widely used average-price method is Geary (1958)-Khamis (1972).[8] In particular, it has been used to make comparisons across the OECD countries and by the International Comparison Program (ICP) to construct the Penn World Table.[9] The Geary-Khamis average prices, p^i_{Xt}, are computed as follows:

$$p^i_{Xt} = \sum_{k=1}^K \left(\frac{q^i_{kt}}{\sum_{j=1}^K q^i_{jt}} \frac{p^i_{kt}}{P^P_{Xt,kt}} \right) \quad \text{for} \quad i = 1, \ldots, N. \tag{7}$$

The average-price vector, p_{Xt}, and Paasche price indexes, $P^P_{Xt,kt}$, are obtained by solving the system of $N + K$ simultaneous equations in (6) and (7).[10]

The fact that average-price methods use the Paasche formula rather than a superlative formula leads to substitution bias in the results which may seriously distort estimates of both per capita income differentials at a point in time and convergence rates over time [see Nuxoll (1994), Dowrick and Quiggin (1997), and Hill (2000)]. This is because the price vector of the artificial country at the center of the star will not be equally representative of the prices faced by all of the countries in the comparison. Geary-Khamis, in particular, tends to underestimate per capita income differentials across countries, since its average-price vector usually approximates more closely the price vectors of the richer countries in the comparison. Hence the substitution bias tends to be larger for poorer countries. This tendency is sometimes referred to as the *Gerschenkron effect* [see Gerschenkron (1951)]. Equally weighted variants on Geary-

[6]An attractive feature of average-price methods is that they generate implicit quantity indexes, when expressed in value terms, that literally add up over different levels of aggregation. This additivity property is particularly useful in national accounts comparisons.

[7]If instead the Laspeyres formula is used, we obtain an Average-Basket method. If a superlative formula is used, then it is necessary to define both an average basket and average price vector.

[8]Another average-price method that has received attention in the literature is the Iklé (1972) method [see Dikhanov (1994)]. A number of other average-price methods are discussed in Hill (2000).

[9]See, for example, OECD (1996), Summers and Heston (1991) and World Bank (1993).

[10]Khamis (1972) proves existence and uniqueness for the Geary-Khamis system.

Khamis, such as Iklé (1972), are also subject to substitution bias. However, for these methods it is less obvious exactly how the results are distorted.

(ii) EKS-Type Methods

The second class, which includes EKS [Eltetö and Köves, (1964) and Szulc (1964)] and CCD [Caves, Christensen and Diewert (1982)], makes bilateral comparisons between all possible pairs of countries. This means that the underlying structure of such methods is a complete graph (see Figure 1). However, to obtain an internally consistent set of multilateral price indexes from a complete graph, the bilateral price indexes must be transitivized using a formula first proposed by Gini (1931). Alternatively, EKS-type methods can be thought of as the combination of K star spanning trees, each of which has a different country at the center. The EKS-type price indexes are obtained by taking the geometric mean of the price indexes generated by these K star spanning trees.

The price index of country k in time period t, P_{kt}, is calculated as follows:

$$P_{kt} = \prod_{j=1}^{K} [(P_{jt,kt})^{1/K}],$$

where $P_{jt,kt}$ denotes the result of a bilateral comparison between countries j and k in period t. The EKS and CCD methods use the Fisher and Törnqvist formulae respectively to make each bilateral comparison. The EKS method is the most widely used method of this type. In particular, it is used by the OECD and Eurostat.[11]

As noted above, EKS-type methods make bilateral comparisons between all possible pairings of countries. It is tempting to conclude that the overall results could be improved by excluding bilateral comparisons between countries with very different consumption patterns. This observation provides part of the motivation for the minimum-spanning-tree (MST) method.[12]

(iii) Spanning-Tree Methods

The third class of multilateral method discussed here uses spanning trees [see Hill

[11]See OECD (1995) and Eurostat (1983).

[12]An alternative approach to dealing with this problem was proposed by Rao (1996). He develops a weighted version of EKS, that allows different weights to be given to each bilateral comparison. See also Rao and Timmer (2000) for a discussion of how these weights can be determined.

(1999a) and (1999b)]. A multilateral comparison between K countries can be made by simply chaining together $K-1$ bilateral comparisons (edges), as long as the underlying graph is a *spanning tree*. A spanning tree is a connected graph that does not contain any cycles. In other words, any pair of vertices in the graph are connected by one and only one path of edges. The reason why there must be no cycles in the graph is to ensure that the multilateral price indexes are transitive and hence internally consistent. A total of K^{K-2} different spanning trees are defined on a set of K vertices. Three examples of spanning trees defined on the set of 5 vertices are shown in Figure 2.[13]

Insert Figure 2 Here

The resulting set of multilateral price indexes depends both on the choice of formula used for making the bilateral comparisons and on the choice of spanning tree. The bilateral comparisons should be made using a superlative formula such as Fisher or Törnqvist.[14] Since superlative formulae satisfy the country reversal test (i.e., $P_{js,kt} = 1/P_{kt,js}$), there is no need for directional arrows on the edges in the spanning tree to identify the base country in each bilateral comparison, and hence it does not matter where one starts in the spanning tree when computing the multilateral price indexes.

The choice of spanning tree is more problematic. A criterion is needed for deciding which edges (bilateral comparisons) to include and which to exclude. Ideally, we should use whichever bilateral comparisons are most reliable. Reliability in this context is measured by the sensitivity of a bilateral comparison to the choice of index number formula. The less sensitive a bilateral comparison is to the choice of formula, the more confidence we can have in the result.

Paasche-Laspeyres Spreads

A number of alternative criteria could be used for measuring the sensitivity of the results of a bilateral comparison to the choice of formula [see Diewert (2002b)]. However, here we follow Hill (1999a) and use Paasche-Laspeyres spreads (PLS). The PLS between country j in period s and country k in period t is defined as

$$PLS_{js,kt} = \left| \ln\left(\frac{P^L_{js,kt}}{P^P_{js,kt}}\right) \right|.$$

[13]Both the star and chain graphs in Figure 1 are also examples of spanning trees.

[14]See Diewert (1976, 1978) for a definition and discussion of the properties of superlative indexes.

The main attraction of the PLS is that it equals zero if either the price data satisfy the conditions for Hicks's (1946) composite commodity theorem (i.e., $p^i_{kt} = \lambda p^i_{js} \;\; \forall i$) or the quantity data satisfy the conditions for Leontief's (1936) aggregation theorem (i.e., $q^i_{kt} = \mu q^i_{js} \;\; \forall i$). In the first case, all bilateral price index formulae give the same answer (i.e., $P_{js,kt} = \lambda$), while in the second case all bilateral quantity index formulae give the same answer (i.e., $Q_{js,kt} = \mu$). Given that price indexes can be derived implicitly from quantity indexes, it follows that in both cases there is no index number problem since the correct price index is exactly determined. By implication, we can have a high degree of confidence in the results of a bilateral comparison with a small PLS, since this suggests that the underlying data are broadly consistent with either Hicks or Leontief aggregation, and the comparison is relatively insensitive to the choice of index number formula.[15]

Minimum-Spanning Trees and Kruskal's Algorithm

A complete graph defined over K vertices has $K(K-1)/2$ edges. Each vertex corresponds to a country and each edge to a bilateral comparison between two countries. The minimum-spanning-tree method for computing multilateral price indexes requires a weight to be placed on each edge (bilateral comparison). Using the Paasche-Laspeyres spreads, $PLS_{jt,kt}$, as weights, the minimum-spanning tree for year t is the spanning tree with the smallest sum of weights on its edges. More precisely, let $v = 1, \ldots, K^{K-2}$ index the set of all possible spanning trees defined on K vertices, and $m = 1, \ldots, K-1$ index the set of PLS in a particular spannning tree (all spanning trees defined on K vertices have $K-1$ edges). In other words, PLS^{vm} denotes the mth PLS in the vth spanning tree. The objective is to find the spanning tree v that solves the following problem:

$$\text{Min}_{v=1,\ldots,K^{K-2}} \sum_{m=1}^{K-1} PLS^{vm}.$$

It turns out that this problem can be solved easily using Kruskal's algorithm.[16] Kruskal's

[15]In addition, in the case of homothetic preferences, since Paasche and Laspeyres price indexes bound the cost-of-living index, a Fisher price index (which by construction lies between Paasche and Laspeyres) must converge on the cost-of-living index as the PLS approaches zero.

[16]See Hill (1999a, 1999b) for a more in depth analysis of the minimum-spanning-tree method. More detailed explanations of Kruskal's algorithm and the concept of a minimum-spanning tree can be found in any introductory book on Graph Theory. For example, see Wilson (1985).

algorithm selects sequentially the edges (bilateral comparisons) with the smallest weights (in our context PLS), subject to the constraint that adding each edge does not create a cycle. The program terminates once $K-1$ edges have been selected, since at this point it is no longer possible to select any more edges without creating a cycle. The resulting graph is the minimum-spanning tree.[17]

If the Paasche-Laspeyres spreads are used as weights, a reasonable case can be made for arguing that the resulting minimum-spanning tree is the spanning tree that minimizes the sensitivity of the *multilateral* price indexes to the choice of *bilateral* index number formula [see Hill (1999a)]. This is because it is constructed from the bilateral comparisons that are least sensitive to the choice of formula.

Multilateral (transitive) price indexes are obtained by chaining a superlative price index such as Fisher or Törnqvist across the minimum-spanning tree. This requires the linking together of $K-1$ bilateral comparisons.

4. Multilateral Comparisons on a Panel Data Set

As will become apparent, the standard multilateral methods are inadequate in a panel context. This is because, in price index comparisons over a panel data set, a tension exists between the spatial and temporal comparisons. This tension manifests itself in the criteria of temporal fixity, spatial fixity, temporal consistency, spatial consistency and temporal displacement. Standard multilateral methods when applied in a panel context violate all five criteria.

(i) Temporal and Spatial Fixity

Temporal fixity is an issue that arises in a panel comparison whenever a new time period is added to the data set. For example, consider a panel data set covering the period 1995-2000. Now suppose data for 2001 become available. Temporal fixity, in this case, is the requirement that the results for the years 1995-2000 are unaffected by the inclusion of the data for 2001. This is a very desirable property, since users of statistics, including government, generally do not like having statistics revised retrospectively.

Spatial fixity is an issue that arises when more countries are added to a multilateral comparison retrospectively. It requires that the results for a core set of countries are

[17] A proof of this result can be found in Wilson (1985).

unaffected by the inclusion of other countries. Spatial fixity for the EU countries is built in to the triennial OECD spatial comparisons.

(ii) Temporal and Spatial Consistency

A panel comparison is *temporally consistent* if it is country separable, i.e., the overall comparison can be broken up into a series of separate temporal comparisons for each country that are then somehow linked together. This means that the temporal results for each country do not depend on the other countries in the comparison.[18]

A panel comparison is *spatially consistent* if it is time separable, i.e., the overall comparison can be broken up into a series of separate spatial comparisons for each year. This means that the spatial results for each year do not depend on the other years in the comparison. In general, it is not possible to maintain both temporal and spatial consistency, while at the same time achieving transitivity.

(iii) Temporal Displacement

Temporal displacement measures the time span between time periods represented in the formula of a bilateral spatial comparison, $P_{jt,kt}$, subsumed within a panel price index comparison. In general, the imposition of transitivity requires that $P_{jt,kt}$ depends on more than just the price and quantity vectors of country-time periods jt and kt. More formally, let $A_{jt,kt}$ and $C_{jt,kt}$ denote, respectively, the set of country-time periods whose price and quantity vectors are used in the bilateral spatial comparison, $P_{jt,kt}$. The elements of $A_{jt,kt}$ and $C_{jt,kt}$ are denoted, respectively, by ab and cd where a and c denote countries and b and d time periods. Hence we can write $P_{jt,kt}$ as a function of the price and quantity vectors p_{ab} and q_{cd} of the elements of $A_{jt,kt}$ and $C_{jt,kt}$.

$$P_{jt,kt} = f[(p_{ab})_1, (p_{ab})_2, \ldots, (p_{ab})_{\alpha_{jt,kt}}, (q_{cd})_1, (q_{cd})_2, \ldots, (q_{cd})_{\gamma_{jt,kt}}],$$

where $\alpha_{jt,kt} \leq KT$, $\gamma_{jt,kt} \leq KT$, and the subscript i in $(p_{ab})_i$ and $(q_{cd})_i$ indexes the elements of $A_{jt,kt}$ and $C_{jt,kt}$. The temporal displacement, $d_{jt,kt}$, of a particular bilateral spatial comparison is measured as follows:

$$d_{jt,kt} = \max_{ab \in A_{jt,kt}, cd \in C_{jt,kt}} (|t - b|, |t - d|).$$

The overall temporal displacement, D, of a panel method is the maximum of the tem-

[18] As will become clear later, neither temporal fixity nor temporal consistency implies the other.

poral displacements of each of the bilateral spatial comparisons within it.

$$D = \max_{j,k,t}(d_{jt,kt}),$$

where $j, k = 1, 2, \ldots, K$ and $t = 1, 2, \ldots, T$. The units of temporal displacement are the same as the intervals between time periods in the panel data set.

Temporal displacement is related to Drechsler's (1973) notion of characteristicity which he introduced in the context of multilateral spatial comparisons. Characteristicity is the idea that a bilateral comparison between countries j and k subsumed within the broader multilateral comparison should as much as possible depend solely on the price and quantity vectors of countries j and k. It is not possible to simultaneously satisfy characteristicity and transitivity, except for degenerate cases where the weight attached to each commodity heading in the price index formulae is the same for all countries.

By implication, all multilateral methods (including all panel methods) violate characteristicity. As far as we are aware, however, no attempt has been made in the index number literature to quantify the extent to which particular methods violate characteristicity. Temporal displacement provides such a measure, from a temporal perspective, for panel price index methods.[19] A higher level of temporal displacement implies reduced characteristicity.

(iv) Six Approaches to Constructing Price Indexes on Panel Data Sets

Each of the panel methods considered here can be modeled as a graph (or combination of graphs). All multilateral spatial comparisons within a graph are made using the EKS method. All bilateral comparisons are made using the Fisher price index. Using a superlative index as the basic building block (EKS indexes are also derived from Fisher indexes) serves the twin objectives of ensuring that the panel methods have firm economic foundations and are free of substitution bias.

Six different panel methods are considered. The performance of each method with respect to temporal consistency, spatial consistency and temporal fixity is assessed. All the methods violate spatial fixity.[20] Discussion of temporal displacement is deferred until later.

[19]To construct an equivalent measure of spatial displacement is more problematic since there is no corresponding natural ordering of countries.

[20]Temporal fixity arises in a systematic way in panel data sets while spatial fixity does not. New

In the empirical analysis later in the paper, these six methods are used to construct price indexes for the 15 member countries of the EU over the period 1995-2000, and the sensitivity of the results to the choice of method are compared. The graphs obtained for these panel methods for the EU data set are shown in this section since they help illustrate the underlying structure of each method.

Minimum-spanning-tree (MST): The MST method can easily be applied to a panel data set. In this context, each vertex corresponds to a country-time period. This means there will be a total of KT vertices in the spanning tree. The bilateral comparisons within the spanning tree are made using the Fisher index. In general, this method violates spatial and temporal consistency and temporal fixity.[21] This undermines its usefulness in a panel context. The MST for the EU countries over the period 1995-2000 is shown in Figure 3.

Insert Figure 3 Here

Minimum-temporally-fixed graph (MTFG): This method constructs the graph in a series of stages. The first stage is to make a multilateral spatial comparison for the first year of the sample, in our case 1995, using the EKS method.[22] In the second stage, the vertices for 1996 are linked to those for 1995, using Kruskal's minimum-spanning-tree algorithm. To ensure temporal fixity, Kruskal's algorithm must collect all the 1995 vertices in one block. This can be guaranteed by specifying low dummy values in the PLS matrix, defined over 1995-6, for the PLS corresponding to comparisons between pairs of countries in 1995. The links between countries in 1995 selected by Kruskal's algorithm are then discarded (i.e., we use only the links involving countries in 1996). In the third stage, the vertices for 1997 are linked to those for 1995-6 in the same manner (i.e., using Kruskal's algorithm). In the fourth, fifth and sixth stages, the vertices for

periods of data are continually added to a panel, while new countries are added only at irregular intervals. Therefore the addition of new countries can be dealt with on a case-by-case basis as the need arises.

[21] Hill (1999a, 2001) finds that spatial MSTs are a lot more sensitive than temporal MSTs to perturbations of the data. Given the presence of spatial data in a panel, panel MSTs will also tend to lack robustness.

[22] In principle, other multilateral methods such as Geary-Khamis could be used. However, in this case the basic building blocks would no longer be superlative bilateral price indexes.

1998, 1999 and 2000, respectively, are included in an analogous manner. By constructing the graph in this sequential manner, temporal fixity is assured. It should be emphasized that temporal fixity and temporal consistency are not equivalent. There is no particular reason to expect the MTFG method to satisfy temporal (or spatial) consistency. The MTFG for the EU for 1995-2000 is shown in Figure 4. Although temporal consistency is violated in Figure 4, the violation is less pronounced than in Figure 3.

Insert Figure 4 Here

Temporally-consistent graph (TCG): Temporally-consistent price indexes will be obtained if the comparison is made by linking together separate temporal comparisons for each country. For example, either the star or chain graph could be used to construct temporal price indexes for each country. A temporally-consistent graph would then be obtained by linking together these stars or chains. The temporally-consistent graph considered here uses chronological-chains for each EU country as building blocks. The 15 chronological chains are linked by an EKS multilateral spatial comparison in any of the 6 years in the sample. As long as the reference year for the spatial comparison is not revised as new years of data are added to the panel, then temporal fixity is also guaranteed. Spatial consistency, however, is violated. An example of a TCG for the EU for 1995-2000 is shown in Figure 6(a).[23]

Spatially-consistent graph (SCG): The SCG is constructed from 6 separate EKS multilateral spatial comparisons, one for each year in the panel. The spatial comparisons could be linked through a chronological chain for a single country (say the one with the smallest summed PLS). Alternatively, 15 sets of results could be generated using each EU country in turn as a chronological chain to link the 6 sets of spatial results together. These 15 sets of results are then averaged using the geometric mean formula: i.e, $P_{kt} = \prod_{j=1}^{K}(P_{jt,kt})^{1/K}$, where $j = 1, \ldots, K$ indexes the 15 EU countries. This approach is analogous to the EKS method which combines comparisons based on star spanning trees with different countries at the center of each star in the same manner.

[23] Alternatively, Kruskal's algorithm could be used to decide how the 15 chronological chains should be linked. This would require the matrix of PLS to be modified to ensure that Kruskal's algorithm selects all 15 chronological chains. In this case, the 14 spatial links between countries would be bilateral and could occur in different years. Temporal fixity would no longer be guaranteed.

The fact that this averaging approach treats all countries symmetrically is often considered highly desirable by international organizations such as the OECD and World Bank (mainly for political reasons). This method is referred to here as GM(SCG). An example of one of the 15 graphs underlying it (for the EU with Germany serving as the link country) is shown in Figure 5. This method violates temporal consistency but satisfies spatial consistency and temporal fixity.[24]

Insert Figure 5 Here

Temporally-fixed grid graph (TFGG): TFGGs are constructed from pure spatial comparisons (i.e., comparisons between countries in the same year) and pure temporal comparisons (i.e., comparisons between time periods for the same country). This means the graph has a grid structure. The TCG and SCG methods in Figures 5 and 6, respectively, also belong to this class. However, here we focus on a subclass of TFGG methods that do not belong to either the TCG or SCG classes.

Suppose EKS spatial comparisons are made at H year intervals, and that temporal comparisons are made using chronological chains, except in the year that a new EKS spatial comparison is made. In such years, the chronological chain of only one country is used. An example of such a method, with the EKS comparisons made at three year-intervals and with Germany as the link country, for the EU is shown in Figure 6(b). Again, 15 sets of results could be generated using each country in turn as the link between 1998 and 1999. Symmetric treatment of countries is obtained by taking a geometric mean of the 15 sets of results. This method is referred to here as GM(TFGG).

It is also possible to take matters a step further and take the geometric mean of GM(TFGG) and the TCG in Figure 6(a), referred to here as GM*(TFGG). One attraction of this method is that the burden of ensuring transitivity is shared by the 1998-9 temporal comparisons and the 1999 spatial comparisons. Both GM(TFGG) and

[24]Alternatively, Kruskal's algorithm could be used to select the 5 temporal links between the 6 EKS spatial comparisons. This can again be achieved using a modified version of the PLS matrix. Now the PLS matrix must be modified to ensure that the edges selected by Kruskal's algorithm link all the vertices in each year in a block. It must be emphasized, however, that all we are interested in here are the 5 temporal links selected by Kruskal's algorithm. All the spatial links are discarded since the spatial comparisons are all made using the EKS method. This method may violate temporal fixity in addition to temporal consistency.

GM*(TFGG) violate temporal consistency whenever a new EKS spatial comparison is made, and spatial consistency except if EKS comparisons are made every year. By construction, however, temporal fixity is satisfied.[25]

Insert Figure 6 Here

Multilateral (M): A multilateral method such as EKS or Geary-Khamis is applied directly to the whole panel of country-time periods. As noted earlier, these methods violate temporal consistency, spatial consistency and temporal fixity.

(v) Choosing Between Panel Price Index Methods

As was discussed earlier, a clear consensus has emerged in the index number literature that temporal price indexes should be constructed by chaining chronologically either Fisher or Törnqvist price indexes. No clear consensus has emerged in the spatial literature with regard to the choice of multilateral formula. This is one reason for giving greater emphasis to maintaining temporal consistency. A second reason for favoring temporal consistency is that temporal data sets tend to be more reliable than spatial data sets. This is because it is easier for a national statistical office to track changes over time in prices and consumption patterns in a country, than it is for an international organization such as the OECD or Eurostat to track changes in prices and consumption patterns across countries. This point has been made previously by Kravis, Heston and Summers (1982):

> [B]oth the benchmark estimates and the growth rates computed from national data have obvious sources of error. The benchmark estimates rely on place-to-place comparisons based on samples of prices that are $\cdots$ smaller than the samples used in the national time-to-time comparisons of prices. It is inherently easier to measure time-to-time changes, at least for items sold off the shelf, because it is possible simply to trace the price of a particular item found in a particular outlet from month to month or year to year. (New products are an exception; their introduction into later benchmark comparisons are likely to be more accurate than their treatment in time-to-time indexes.) $\cdots$ If there is a little variation in quality from one outlet to

[25] The geometric mean of two or more temporally-fixed methods will also satisfy temporal fixity.

> another, that does not matter so long as the same quality in a given outlet is priced in each period. It is much more difficult to get the average national price for a particular specification of a good in any one country. Then it is necessary to ensure that the same quality of each good is priced in every outlet. Further possibilities of error are introduced in place-to-place comparisons by the need to hold quality constant not only within each country, but across countries as well. [Kravis, Heston and Summers (1982, p. 326)]

For these reasons, a reasonably strong case can be made for using chronological chains for each country as building blocks in a panel comparison (i.e., TCG methods). Assuming, as is usually the case, a panel comparison will be updated in due course as new time periods are added to the data set, temporal fixity is also important.[26]

This suggests, therefore, that we should prefer methods that maintain temporal fixity and temporal consistency. This seems to lead us to the TCG method depicted in Figure 6(a) since it satisfies both conditions. However, so far we have ignored the criterion of temporal displacement. The temporal displacement of the TCG method cannot be less than $(T-1)/2$, where T denotes the number of time periods in the panel. The temporal displacement is minimized when the reference EKS spatial comparison is made in the middle year of the panel. In contrast, the temporal displacement of GM(TFGG) is $H-1$, where H denotes the time interval between EKS spatial comparisons. Similarly, for GM*(TFGG) the temporal displacement is H. (By contrast, it is worth noting that the temporal displacement, in a panel context, of standard multilateral methods such as EKS,and Geary-Khamis is $T-1$.)

Over time, as more periods are added to the panel, T rises while H stays the same. Hence, GM(TFGG) becomes increasingly attractive relative to TCG with regard to temporal displacement as T rises. Also, as T rises, TCG methods must extrapolate a single multilateral spatial comparison over more and more years. This may lead to drift in the spatial results in years further away from the spatial reference year. For example, consider a panel data set covering the period 1982-2002. Suppose further that

[26] In contrast, as noted earlier, spatial fixity can be dealt with on a case-by-case basis. For example, new member countries in the EU could be added to EU comparisons retrospectively, by linking them through bilateral comparisons with a bridge country, such as Austria.

the panel comparison is made using TCG with the multilateral spatial comparison in 1985. In this case, the temporal displacement would be 17. This means that France and Germany in 2002 are compared indirectly via an EKS comparison in 1985. It is precisely to avoid such scenarios that chaining has been advocated over fixed-base comparisons in the temporal index number literature. (For example, a fixed-base comparison with 1985 as the base would compare 2001 and 2002 indirectly via 1985.) This problem of drift in the spatial results obtained by extrapolating from a previous multilateral spatial comparison is exacerbated by the different treatment in the CPI of hedonic price adjustment methods for computers and other products experiencing rapid quality change across countries. In such cases, the methods GM(TFGG) and GM*(TFGG) with EKS spatial comparisons made at 3 or 5 year intervals may be preferable since they allow the reference multilateral spatial comparison to be updated regularly, thus keeping the temporal displacement reasonably low. This comes at the price of a violation of temporal consistency with each new EKS spatial comparison.

(vi) Reconciling Temporal and Spatial Price Indexes

The conflict between temporal and spatial consistency also arises in a different although related context. Suppose a researcher wants to combine temporal price indexes from one source with spatial price indexes from another source. If spatial results for more than one period are used, then a problem of intransitivity (i.e., internal inconsistency) in the results will arise. For example, price levels across countries in the EU can be compared by combining the consumer price indexes (CPIs) for each country with OECD spatial price indexes. The OECD spatial price indexes are available at 3-year intervals. Over the period 1995-2000, OECD spatial results are available for 1996 and 1999. This case is graphed in Figure 7 for 5 EU countries. Irrespective of the choice of multilateral method for making the spatial comparisons in 1996 and 1999, there will be cycles in the graph and hence the results will be intransitive. For example, consider the following comparison: France98-France99 (Fr98-Fr99). This comparison can be made directly or indirectly. An indirect comparison can be made in an infinite number of different ways, many of which will give different answers. Here we consider just 5 of the indirect methods.

Insert Figure 7 Here

Indirect path 1: Fr98-FR97-Fr96-Ge96-Ge97-Ge98-Ge99-Fr99

Indirect path 2: Fr98-FR97-Fr96-It96-It97-It98-It99-Fr99

Indirect path 3: Fr98-FR97-Fr96-Sp96-Sp97-Sp98-Sp99-Fr99

Indirect path 4: Fr98-FR97-Fr96-UK96-UK97-UK98-UK99-Fr99

Indirect path 5: Fr98-FR97-Fr96-Ge96-Ge97-Ge98-Ge99-It99-It98-It97-It96-UK96-UK97-UK98-UK99-Fr99

The panel methods discussed above can be used to impose transitivity in Figure 7. The case for using the TCG method is not as strong in this context. This is because it implies ignoring completely the multilateral spatial comparison for either 1996 or 1999. In addition, as noted earlier, as the number of years in the panel rises TCG becomes increasingly unsatisfactory since drift may occur in the spatial results. For these reasons, GM(TFGG) and GM*(TFGG) may be preferable since they make full use of the available data and allow for periodic updating of the spatial reference. GM*(TFGG) is particularly attractive since it allows the burden of ensuring transitivity to be shared by the 1998-9 temporal and 1999 spatial comparisons.

Another approach to resolving this problem was proposed by Summers and Heston (1984) which they refer to as "consistentization" [see also Aten and Heston (2002)]. They begin by assuming that both the temporal and spatial price indexes contain errors. They then run a regression that imposes transitivity by minimizing the least squares deviations from the original price indexes. Aten and Heston note, however, that:

> Because of the reluctance of countries to accept adjustments of their national indexes of growth and price change, we have not pursued this approach in developing PWT 5.6 and 6.0." [Aten and Heston (2002, p. 3)]

In other words, the Summers and Heston approach violates temporal consistency (in all periods and not just the one of a new spatial comparison). A stronger objection perhaps is that this approach also violates temporal fixity.

5. An Application of Panel Price-Index Methods to the EU

(i) Constructing a Panel Data Set

Before these panel methods can be used, it is first necessary to construct a suitable panel data set. This is achieved by splicing together the Harmonized Index of Consumer Prices (HICP) at as disaggregated a level as possible with a cross-section of OECD data.

The HICP data used here cover the period 1995-2000, and consist of annual prices and quantities for 96 distinct commodity headings, and country weights for the 15 member countries of the European Union (EU).[27] However, not all headings are available for all countries. To ensure comparability, in some cases we use more aggregated headings. In consequence, the number of headings is reduced to 82. For all countries, the price for each heading is normalized to 100 in 1996. The quantities each year sum to 1000 for each country. The country weights also sum to 1000. In addition, monthly prices for the 96 headings are also available. However, there are no corresponding quantities and country weights at the monthly frequency. Hence our analysis here focuses exclusively on the annual data. Using this data set it is possible to construct temporal price indexes that measure changes in the purchasing power of currencies and the price level in EU countries over time. However, it is not possible to construct spatial price indexes that compare the purchasing power of currencies and the price level at a given point in time. Such comparisons can be made using OECD cross-section data. Since 1990 the OECD makes detailed cross-section comparisons of GDP at three-year intervals of its member countries and associated countries in Eastern Europe and the Confederation of Independent States (CIS). This means that two sets of detailed cross-section price and quantity data are available during the period 1995-2000: namely for 1996 and 1999.

The aim here is to simultaneously compute both temporal and spatial price indexes for the EU member countries. To do this it is necessary to merge the EU and OECD price data at the basic heading level in either 1996 or 1999. Since two sets of spatial results are available, the immediate question arises as to which should be used? Alternatively, both could be used. However, then there would be cycles and hence intransitivities in the heading data itself, which would have to be fixed before we could even contemplate constructing any price indexes. Furthermore, the 1996 and

[27] For a thorough review of the HICP and its properties see Diewert (2002a).

1999 OECD headings do not correspond exactly, which would further complicate this process. In this section we sidestep these issues by using only the 1996 OECD spatial comparison. Our justification for doing this is that our objective is to focus on how price indexes should be constructed on a panel data set, rather than on how the panel data set itself should be constructed.

The 1996 OECD data set has 162 headings. The first step is to remove the headings relating to capital formation and government consumption, since there are no corresponding HICP headings. This still leaves 141 OECD headings, which must then be matched with the 82 HICP headings. The harmonized data set was constructed to have exactly the same headings as the HICP data set. Only 39 OECD and HICP headings could be matched up exactly. Of the remaining 43 headings in the harmonized data set, 23 were created by matching more than one OECD heading with one HICP heading. For example, 6 OECD headings were combined to match the HICP heading "bread and cereals". The OECD headings were merged using the EKS price index formula (see below). Of the remaining 20 headings, in 7 cases an OECD heading was applied to 2 HICP headings, in 1 case an OECD heading was applied to 3 HICP headings, and in the last case 2 OECD headings were matched with 3 HICP headings. The exact matching of headings is shown in Table 1.

Insert Table 1 Here

Once the harmonization of the two data sets in 1996 is complete, the final step is to scale up or down accordingly each price heading in the HICP data set for each country in 1995 and 1997-2000. As discussed above, in the original HICP data set the prices of all headings in 1996 are normalized to 100. In the harmonized data set – like the OECD data set – the prices in 1996 are normalized to 100 for only one country (Austria). The choice of reference country does not affect the results. Using this harmonized data set, it is now possible to make spatial as well as temporal comparisons across the 15 EU countries.

(ii) Sensitivity of the Results to the Choice of Panel Method

Price indexes for the 15 EU countries over the period 1995-2000 are shown in Table 2. The price indexes are computed using the six panel methods described in the previous section. Two versions of the last method [M(EKS) and M(GK)] are used. This means there are a total of 7 sets of results. For all 7 sets of panel results in Table 2 the price index for the UK in 1996 is normalized to 1. For example, referring to Table 2, we can deduce that, according to the MST method, one British pound in 1996 had the same purchasing power as 57 Belgian francs in 2000.

Insert Table 2 Here

Greece-98 (Gr98) is the observation in Table 2 that is most sensitive to the choice of method. The number of 1998 Drachmas that have the same purchasing power as one 1996 British pound varies from 375 to 407.[28] By the standards of international comparisons, the results in Table 2 are not that sensitive to the choice of method, particularly if we exclude the results obtained using the Geary-Khamis method. This is probably because the set of EU countries are reasonably homogeneous, and because the underlying data are not that disaggregated (only 82 headings). This tends to reduce the magnitude of the observed substitution effect, which drives the sensitivity of the results to the choice of index number method [see Manser and McDonald (1988)].

The similarity of the overall results generated by each method can be compared using the similarity index, L_{ab}, defined below:

$$L_{ab} = 100 \left\{ \frac{1}{KT} \sum_{t=1}^{T} \sum_{k=1}^{K} \left[\frac{\max\left(P_{kt}^{a}, P_{kt}^{b}\right)}{\min\left(P_{kt}^{a}, P_{kt}^{b}\right)} \right] - 1 \right\},$$

where P_{kt}^{a} denotes the price index in country k in period t obtained using method a. Two attractive features of L_{ab} are first that it is symmetric (i.e., $L_{ab} = L_{ba}$), and second that it is invariant to the choice of base country-time period. For example, in Table 2 the reference country-time period is the UK in 1996. However, if it was changed say to Germany in 2000, L_{ab} would be unaffected.

Table 3 shows the L_{ab} measures obtained from comparisons between all possible pairs of the 7 panel methods. Not surprisingly, M(GK) is the main outlier. The M(GK) results differ on average by between 1.69 and 3.12 percent, depending on the method it is compared with. This is not surprising since all the other methods use Fisher price indexes as their basic building blocks either directly or indirectly via the EKS method. The two methods that approximate each other most closely are TCG and GM*(TFG)

[28]It should be noted that the observed sensitivity of each observation to the choice of method is not independent of the choice of base country-time period.

(differing by only 0.039 percent). This also is not surprising since these methods by construction are identical for the years 1995-8.

Insert Table 3 Here

6. Testing for Convergence of Price Levels and Relative Prices

(i) Comparing Price Levels

The price level in country k relative to country b in period t, Z_{kt}/Z_{bt}, is defined here as follows:

$$Z_{kt}/Z_{bt} = \frac{P_{kt}/P_{bt}}{X_{kt}/X_{bt}},$$

where X_{kt}/X_{bt} denotes the exchange rate of country k in period t expressed as the number of units of currency in country k that can be exchanged for one unit of currency in the base country b in period t.[29] The resulting price levels for each of the 7 panel methods considered above are shown in Table 4, with Germany serving as the base country. For each year, therefore, the price level in Germany is normalized to one.

Insert Table 4 Here

The price-level rankings of the 7 panel methods are similar, although not identical. The three Scandinavian countries (Denmark, Sweden and Finland) have the highest price levels in the EU (about 20 percent higher than Germany), while Greece, Portugal and Spain have the lowest (about 25 percent lower than Germany). The price-level rankings do not change much from one year to the next. This systematic tendency towards lower price levels in poorer countries (in our case Greece, Portugal and Spain) can be explained by the fact that nontradables, in general, are more labor intensive and hence relatively cheaper in these more labor abundant countries. In other words, there is no reason to expect purchasing power parity to hold even in the long-run unless real income levels converge [see Kravis and Lipsey (1983) and Bhagwati (1984)].

Differences in price levels across the EU in a given year can be measured by the standard deviation of the logarithm of the price level, Z_{kt}, across the set of countries $k = 1, \ldots, K$.

$$I_t = \sqrt{\frac{1}{K-1} \sum_{k=1}^{K} \left[\ln\left(\frac{Z_{kt}}{Z_{bt}}\right) - \overline{\ln\left(\frac{Z_t}{Z_{bt}}\right)} \right]^2},$$

[29] The exchange rates used are yearly averages obtained from the Yearbook of International Financial Statistics (2001) published by the IMF.

$$\text{where} \quad \overline{\ln\left(\frac{Z_t}{Z_{bt}}\right)} = \frac{1}{K}\sum_{k=1}^{K}\ln\left(\frac{Z_{kt}}{Z_{bt}}\right).$$

I_t is invariant to the choice of base country b (in this case Germany). Estimates of I_t over the period 1995-2000 for each of the 7 multilateral methods are shown in Table 5.[30]

Insert Table 5 Here

A decrease in I_t over time signals that price levels are converging. This corresponds to the concept of σ-convergence in the growth-convergence literature [see Barro and Sala-i-Martin (1992), Quah (1996), and Dowrick and Quiggin (1997)]. Interpretation of the results is complicated by the fact that the set of countries is not the same across all years. The years 1996-1999 cover all 15 EU countries. However, Greece is missing in 2000 and Austria, Denmark, France, Luxembourg and the UK are missing in 1995. Hence we exclude 1995 from Table 5, and provide two sets of results, one covering the period 1996-1999 for all 15 EU countries, and one excluding Greece covering the period 1996-2000. Between 1996 and 1999, according to all 7 panel methods, price levels converged (i.e., I_t fell over time). Excluding Greece, over the period 1995-2000, the same pattern is observed, although in the final year prices diverged.[31] The consensus between the 7 methods regarding convergence is broken, however, if we consider the period 1997-2000 excluding Greece. In this case 6 panel methods show convergence while one (SCG) shows divergence.

(ii) Comparing Relative Prices

The similarity of the price vectors of two countries j and k in period t can be measured using a variant on the measure I_t discussed above. However, now what is measured is the standard deviation of the logarithm of the price relatives, p^i_{kt}/p^i_{jt}, across the set of goods $i = 1, \ldots, N$. Also, it is necessary to weight each commodity heading by its average expenditure share.

$$S^t_{jk} = \sqrt{\sum_{i=1}^{N}\left(\frac{s^i_{jt}+s^i_{kt}}{2}\right)\left[\ln\left(\frac{p^i_{kt}}{p^i_{jt}}\right) - \overline{\ln\left(\frac{p_{kt}}{p_{jt}}\right)}\right]^2}, \tag{8}$$

[30] Methods TCG, SCG and GM*(TFG) all make a spatial comparison in 1996 using the EKS method. Hence, by construction, I_t must be the same for these three methods in 1996.

[31] For every method I_t is smaller when Greece is excluded. This shows that Greece is an outlier.

$$\text{where} \quad \overline{\ln\left(\frac{p_{kt}}{p_{jt}}\right)} = \sum_{i=1}^{N}\left[\left(\frac{s_{jt}^i + s_{kt}^i}{2}\right)\ln\left(\frac{p_{kt}^i}{p_{jt}^i}\right)\right],$$

and s_{kt}^i denotes the expenditure share of good i in country k in time period t, as defined in (4). The log transformation ensures that S_{jk}^t is symmetric (i.e., $S_{jk}^t = S_{kj}^t$).

A measure of the similarity of relative prices across the EU in a given year is obtained by taking the geometric mean of S_{jk}^t, denoted by $G(S_{jk}^t)$, across all pairs of countries.

$$G(S_{jk}^t) = \prod_{j=1}^{K}\prod_{k=1}^{K}\left[S_{jk}^t\right]^{1/K^2}$$

Estimates of $G(S_{jk}^t)$ for the period 1996-1999 for all 15 EU countries and for 1996-2000 excluding Greece are shown in Table 6. Irrespective of whether or not Greece is included, the results suggest that relative prices have diverged slightly over this period.[32]

Insert Table 6 Here

7. Implications of Findings

Our finding of slight price level convergence in Table 5 is consistent with Rogers (2001). Rogers computes price level indexes for 18 countries (including all members of the European Union) in 1990, 1995 and 1999 using a data set constructed by combining price data from the Economist Intelligence Unit (EUI) with HICP expenditure data.[33,34] Rogers finds evidence of faster convergence in the first half of the 1990s than in the second half (the period covered in this paper). Rogers then goes on to discuss

[32]It is not clear how robust the findings with regard to convergence in Tables 5 and 6 are to changes in the level of aggregation of the data. The HICP commodity headings are already quite aggregated. If more disaggregated data were used, the results might be different.

[33]The EUI data set consists of prices of 168 goods and services in 26 cities in 18 countries. When data on two or more cities in the same country were available, Rogers averaged the prices, to obtain a single set of prices for each country. Expenditure weights were obtained by matching the goods and services in the EUI data set with the headings in the HICP. If more than one good or service were matched with a particular HICP heading, then Rogers used an average price.

[34]This data set is a panel, although Rogers uses only one set of expenditure shares (corresponding to an unspecified year). This means that all his price indexes are of either the Paasche or Laspeyres variety. Nevertheless, this data set could be used to address some issues of price index construction on panel data sets. Given Rogers is interested primarily in price level convergence, however, he does not address this issue.

the implications of price level convergence for the European Central Bank (ECB). A necessary implication is that countries with initially lower price levels on average must experience higher rates of inflation during the transition. Differing inflation rates within the Euro-zone countries means that monetary policy may be too stimulative in some countries and too restrictive in others. This problem could become more severe if the Euro-zone is widened to include relatively low-price countries in Eastern Europe.

Our second finding that relative prices have diverged slightly over the same period (1995-2000) is somewhat surprising, given the concurrent tendencies towards greater economic integration in the European Union, and the observed convergence in price levels. As far as we know, this trend has not previously been observed. As noted above, it is not clear how robust it is, and whether the same trend would be observed for more disaggregated data. However, assuming the result is not spurious, the challenge then is to reconcile it with the observed trend towards greater economic integration and price level convergence.

One possible explanation is that the convergence of prices has been focused predominantly on tradable goods, and that as a result the relative price of tradables and nontradables have diverged enough to cause overall relative prices to diverge. This explanation, however, is not borne out by the results in Tables 7 and 8. Table 7 shows separate price similarity indexes for tradables and nontradables over the period 1996-2000. Table 7 was constructed by separating the 82 headings into tradables (54 headings) and nontradables (28 headings). The results in Table 7, which were derived using the TCG panel method in Figure 6(a), clearly indicate convergence in both tradable and nontradable price levels. As expected, I_t is bigger for nontradables. Table 8 measures the price similarity of tradables and nontradables. To construct Table 8 it was first necessary to compute separate tradable and nontradable price indexes. These were then fed into equation (8) with $N = 2$, and $G(S_{jk})$ again obtained by averaging S_{jk} over all possible pairings of countries. The results in Table 8 show that the relative price of tradables and nontradables converged over the period 1995-2000. The observed divergence of relative prices in Table 6, therefore, remains to be explained.

8. Conclusion

This paper has focused on two main issues. First and foremost it has developed a methodology for constructing panel price indexes, which can also be used for reconciling temporal and spatial price indexes. Given the greater consistency of temporal data (in terms of construction) and the fact that changes in prices and expenditure patterns over time tend to be rather smaller than differences in prices and expenditure across countries, it is usually preferable to try and build up a panel comparison from temporal rather than spatial comparisons. When the time span of the panel data set is reasonably short, this leads to the TCG method of the type shown in Figure 6(a), which combines a single multilateral spatial comparison with chronologically chained temporal comparisons. This approach becomes increasingly unsatisfactory, however, for longer time spans as the process of extrapolating a single multilateral spatial comparison causes drift in the spatial results for other years. In such cases, the GM*(TFGG) method may be preferable. When reconciling spatial and temporal price indexes, the case for using the GM*(TFGG) is even stronger, since it makes greater use of the available data.

The second focus of the paper is the application of the panel methodology to the European Union. To do this, it was first necessary to compute a suitable panel data set. This was achieved by merging a cross-section of OECD data with the EU's HICP at a disaggregated level. This merged HICP/OECD data set is used to compare price levels and relative prices across countries in the EU over the period 1995-2000. Price levels converged slightly while relative prices diverged. This last finding warrants further investigation.

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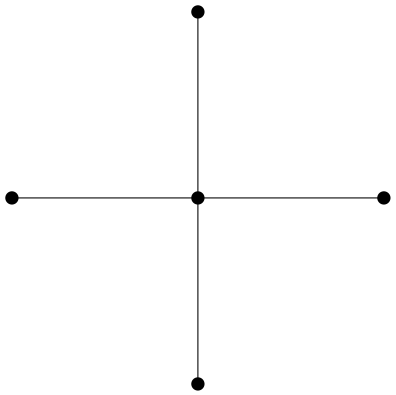
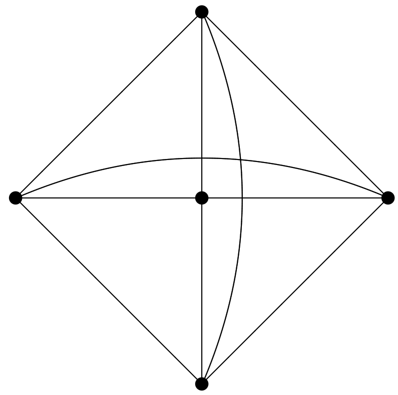
FIGURE 1. — EXAMPLES OF GRAPHS



Star Graph



Complete Graph

Chain Graph

FIGURE 2. — EXAMPLES OF SPANNING TREES

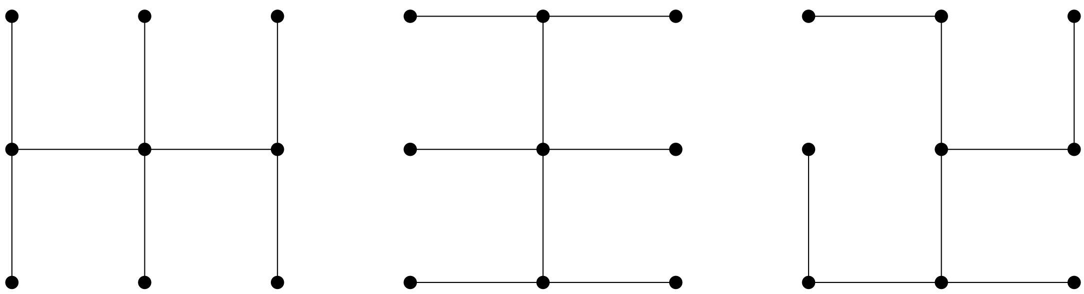


FIGURE 3. — MINIMUM SPANNING TREE FOR EUROPEAN UNION (1995-2000)

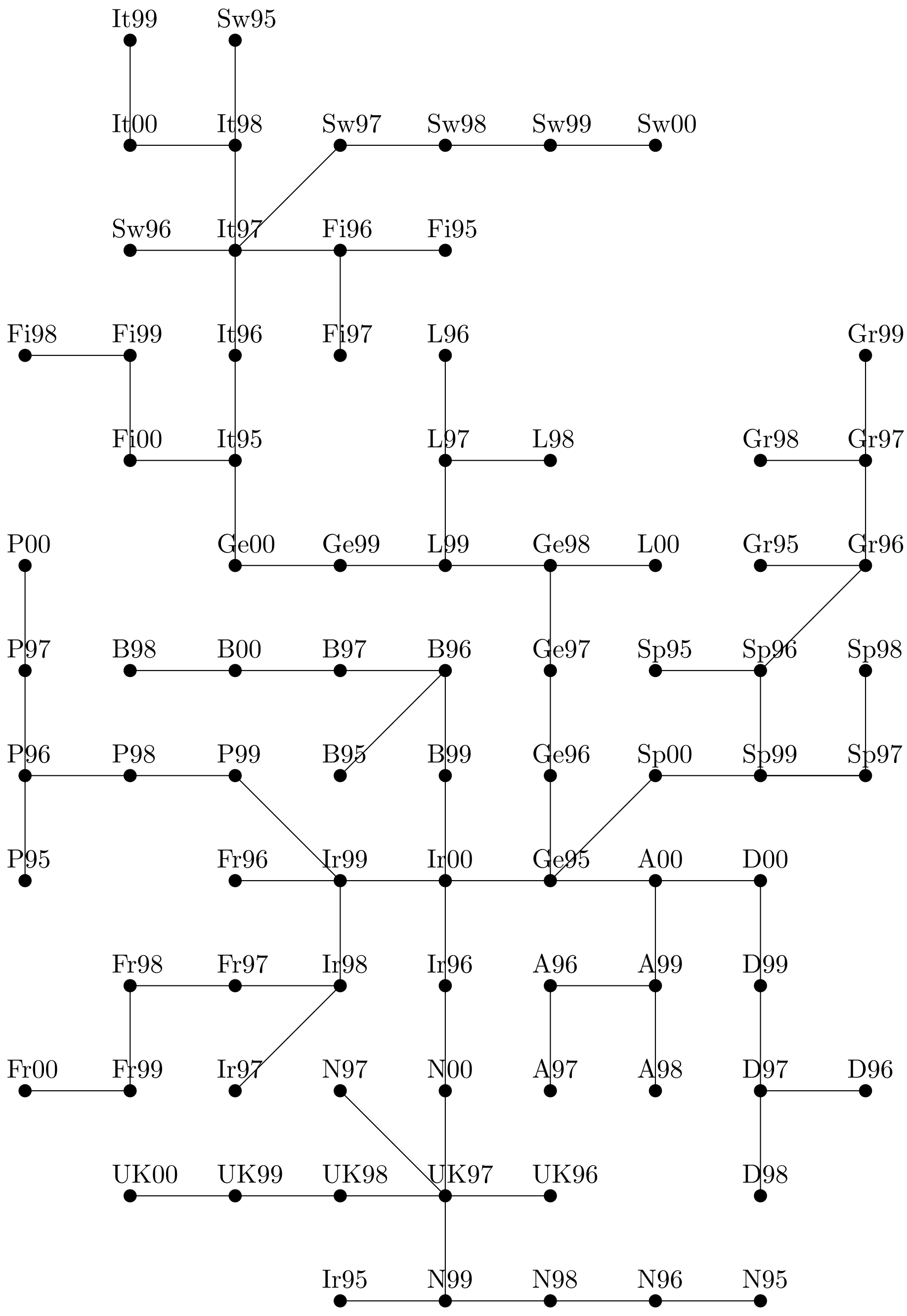


FIGURE 4. — MINIMUM TEMPORALLY FIXED GRAPH FOR THE EUROPEAN UNION (1995-2000)

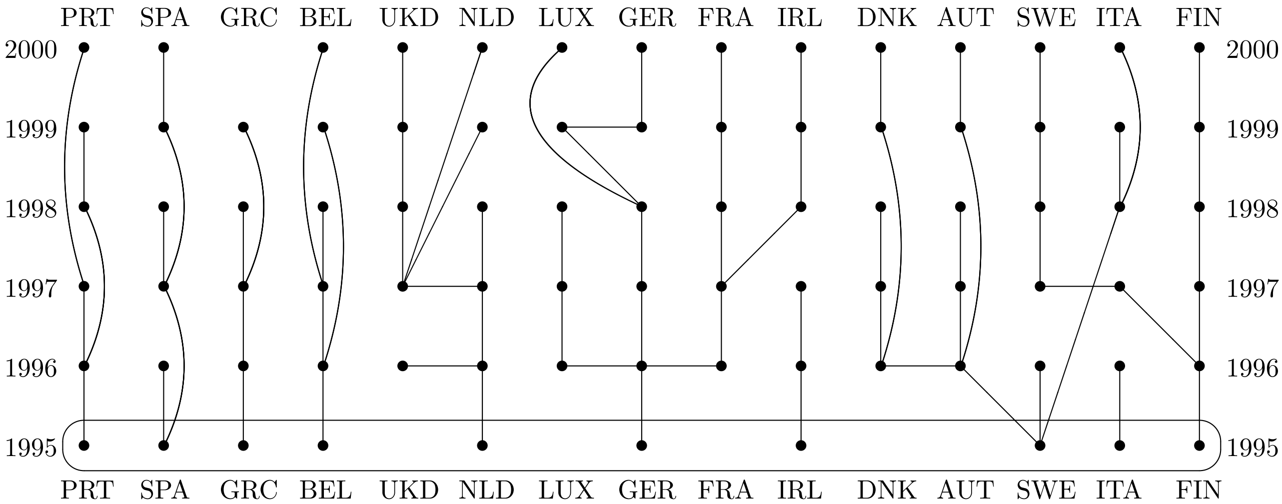


FIGURE 5. — SPATIALLY CONSISTENT GRAPH FOR THE EUROPEAN UNION (1995-2000) WITH GERMANY AS LINK COUNTRY

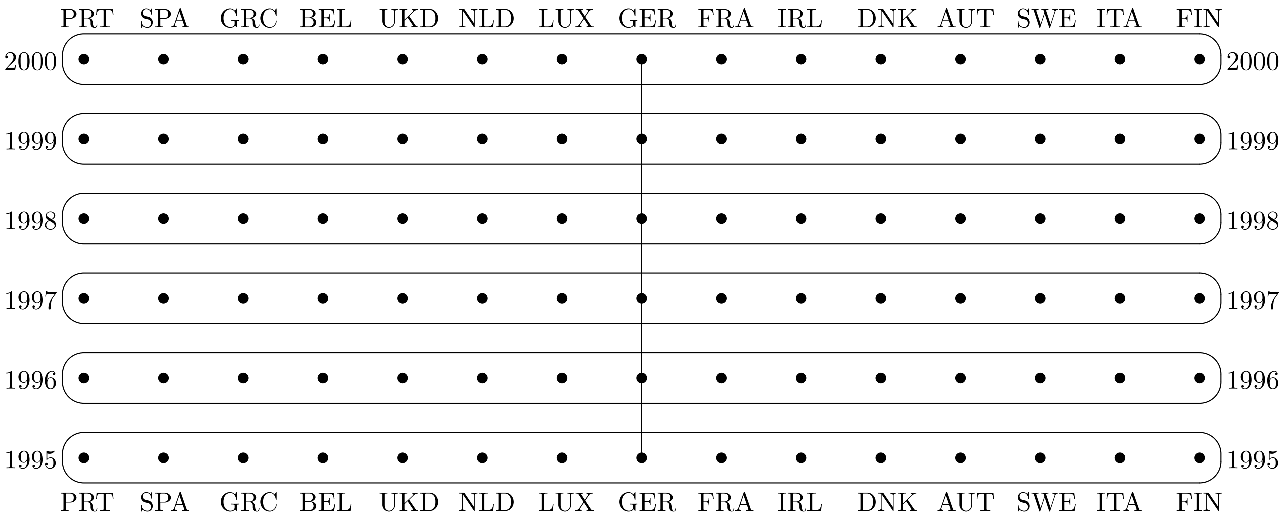
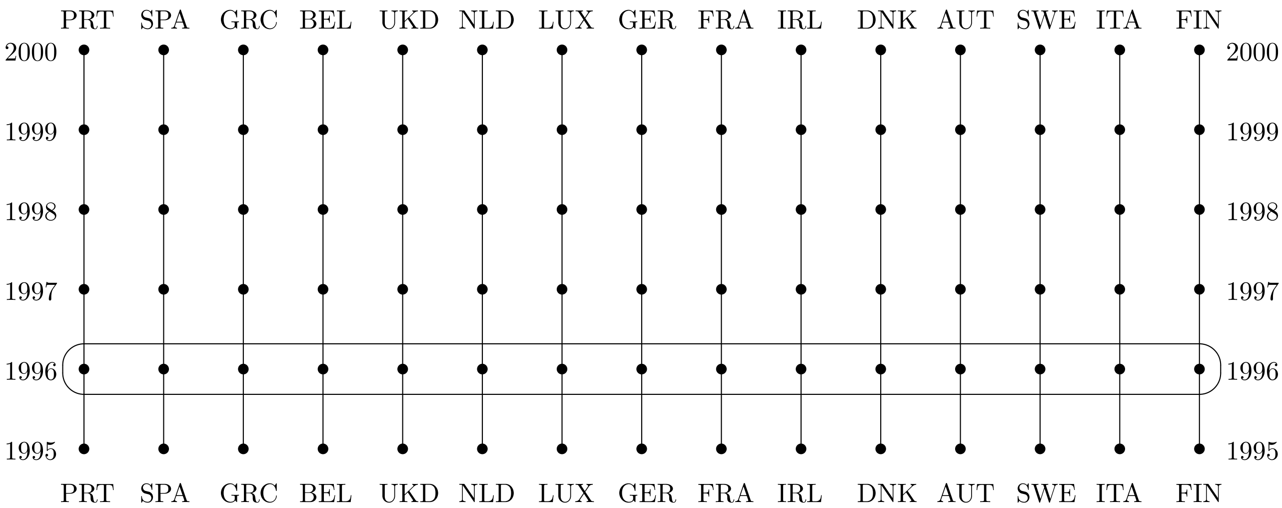
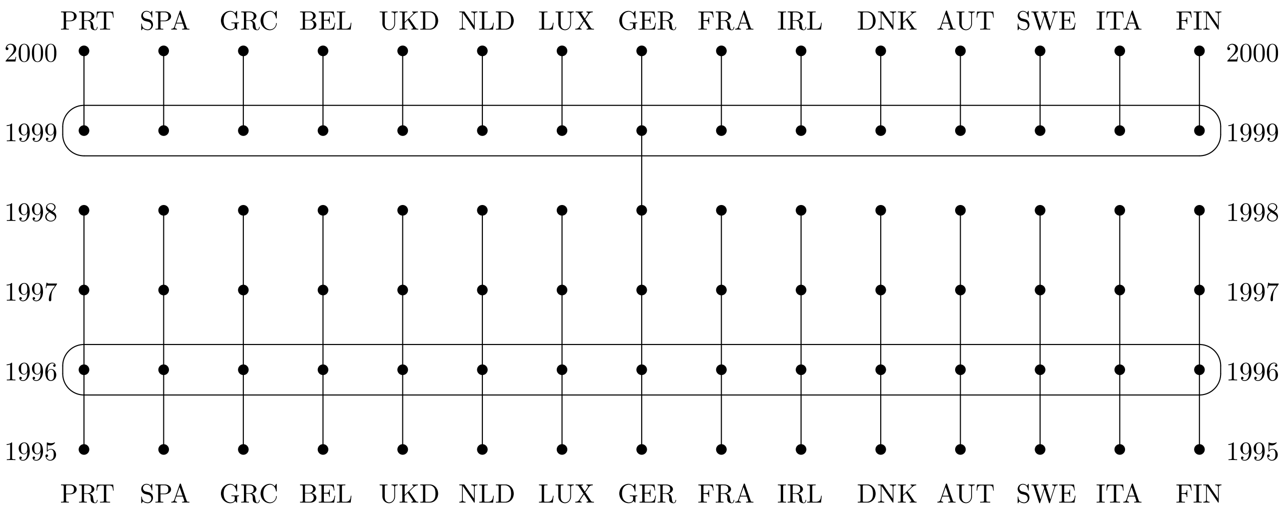


FIGURE 6. — TEMPORALLY FIXED GRAPHS FOR THE EUROPEAN UNION (1995-2000)



(a) Temporally Fixed (Consistent) Graph with Spatial Link in 1996



(b) Temporally Fixed Graph with Germany as the Link Between 1998 and 1999

FIGURE 7. — RECONCILING SPATIAL AND TEMPORAL PRICE INDEXES

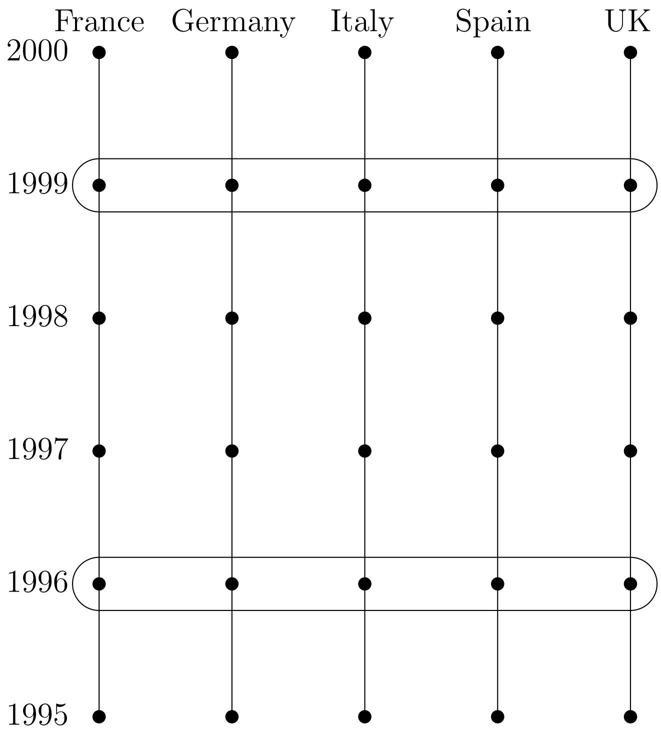


TABLE 1. MATCHING OF OECD AND HICP DATA SETS

OECD Heading		HICP Heading
1111011	Rice	cp0111 Bread and cereals
1111012	Flour & other cereals	
1111013	Bread	
1111014	Rusks,imperishable bakery products	
1111015	Pasta products	
1111016	Other cereals products	
1111021	Beef	cp0112 Meat
1111022	Veal	
1111023	Pork	
1111024	Lamb,mutton,goat	
1111025	Poultry	
1111026	Delicatessen	
1111027	Proces. & preser.meat prep.in cans,jars	
1111028	Edible offal and other meats	
1111031	Fresh and frozen fish	cp0113 Fish and seafood
1111032	Dried,smoked or salted fish	
1111033	Fresh or frozen seafood	
1111034	Preserv. & processed fish and seafood	
1111041	Fresh milk	cp0114 Milk, cheese and eggs
1111042	Preserved milk	
1111043	Other milk products	
1111044	Cheese	
1111045	Eggs and egg-based products	
1111051	Butter	cp0115 Oils and fats
1111052	Margarine	
1111053	Edible oils	
1111054	Other animal and vegetable fats	
1111061	Fresh fruit	cp0116 Fruit
1111062	Dried fruit & nuts	
1111063	Frozen & preserved fruit, etc.	
1111064	Fresh vegetables	cp0117 Vegetables
1111065	Dried vegetables	
1111066	Frozen vegetables	
1111067	Pres.vegetables & veg.-based products	
1111068	Potatoes, other tuber vegetables	
1111069	Potato products	
1111071	Sugar (raw and refined)	cp0118 Sugar, jam, honey, chocolate
1111075	Jams, jellies, honey and syrups	
1111076	Chocolate & oth.cocoa preparations	
1111077	Confectionery	
1111072	Coffee	cp0121 Coffee, tea and cocoa
1111073	Tea and other infusions	
1111074	Cocoa (excl.cocoa preparations)	
1111078	Ice cream	cp0119 Food products n.e.c.
1111079	Condiments & oth.food products nec	
1112011	Bottled water	cp0122 Mineral waters, soft drinks, fruit, juices
1112012	Other soft drinks nec.	
1112022	Spirits and liqueurs	cp0211 Spirits
1112023	Wine	cp0212 Wine
1112024	Beer	cp0213 Beer
1112025	Other alcoholic beverages	
1113011	Cigarettes	cp022 Tobacco
1113021	Other tobacco products	

TABLE 1. MATCHING OF OECD AND HICP DATA SETS

1121011	Men's clothing	cp0311 Clothing materials
1121012	Ladies' clothing	
1121013	Children's clothing	
1121014	Infant's clothing	
1121015	Materials, yarns, accessories, etc.	cp0312 Garments
		cp0313 Other articles of clothing and accessories
1121021	Repair and maintenance of clothing	cp0314 Cleaning, repair and hire of clothing
1122011	Men's footwear	cp032 Footwear including repair
1122012	Women's footwear	
1122013	Children's and infant's footwear	
1122021	Repairs to footwear	
1131011	Rents of tenants in flats & houses	cp041 Actual rentals for housing
1131013	Repair and maintenance of housing	cp0431 Materials for maintenance/repair of dwelling
		cp0432 Services for maintenance/repair of dwelling
1132011	Electricity	cp0451 Electricity
		cp044 Water/miscellaneous services to dwelling
1132021	Town gas and natural gas	cp0452 Gas
1132022	Liquefield petroleum gas (butan etc.)	cp0455 Heat energy
1132031	Liquid fuels	cp0453 Liquid fuels
1132041	Coal, coke and other solid fuels	cp0454 Solid fuels
1141011	Furniture and fixtures	cp0511 Furniture and furnishings
1141012	Carpets and other floor coverings	cp0512 Carpets and other floor coverings
1141021	Repairs to furniture,fixtures etc.	cp0513 Repair of furniture, furnishings, floor coverings
1142011	Household textiles, other furnishings	cp052 Household textiles
1142021	Repairs to household textiles etc.	
1143011	Refrigerators,freezers & fridge fr.	cp0531/2 Major/small electric household appliances
1143012	Washing machines,spin driers etc.	
1143013	Cookers, hobs and ovens	
1143014	Heaters and air-conditioners	
1143015	Vacuum cleaners,polishers etc.	
1143016	Other major household appliances	
1143021	Repairs to major household appliances	cp0533 Repair of household appliances
1144011	Glassware and tableware	cp054 Glassware, tableware and household utensils
1144012	Cutlery and flatware	
1144013	Motorless kitchen & domestic utensils	
1144014	Motorless garden appliances	cp055 Tools and equipment for house and garden
1144015	Small electrical accessories	
1144021	Repairs to glassware,tableware etc.	
1144031	Cleaning and maintenance products	
1144032	Other non-durable household goods	cp0561 Non-durable household goods
1144041	Laundry and dry cleaning	cp0562 Domestic services and household services
1144051	Domestic services	
1150000	MEDICAL CARE	cp06 Health
1161011	Passenger vehicles	cp0711 Motor cars
1161021	Motorcycles and bicycles	cp071_not_711 Motor cycles, bicycles, etc
1162011	Tyres, tubes, parts, accessories	cp0721 Spares parts for personal transport equipment
1162012	Maintenance and repair services	cp0723 Maintenance of personal transport equipment
1162021	Motor fuels,oils and greases	cp0722 Fuels/lubricants for personal transport equip.
1162031	Oth. expenses: to pers.transport	cp0724 Other services for personal transport equip.
1163011	Local by bus, train, tube, tram, taxi	cp0731 Passenger transport by railway
1163021	Long distance by coach and rail	cp0732 Passenger transport by road
		cp0735 Combined passenger transport
1163022	Long-distance transport: air + sea	cp0733 Passenger transport by air
		cp0734 Passenger transport by sea/inland waterway

TABLE 1. MATCHING OF OECD AND HICP DATA SETS

1163031	Other purchased transport services	cp0736 Other purchased transport services
1164011	Postal services	cp081 Postal services
1164021	Telephone, telegraph, telex services	cp08233 Telephone/telefax equipment and services
1171011	Radios & electro-acoustic apparatus	cp0911 Sound and picture recording equipment, etc
1171012	Television-sets and videorecordes	
1171021	Photographic and related equipment	cp0912 Photographic, cinematographic, optical equip.
1171022	Other durable recreational goods	cp0913 Information processing equipment
1171031	Records,tapes,cassettes(audi&video)	cp0914 Recording media
1171032	Sports goods and camping equipment	cp0932 Equipment for sport, camping and recreation
1171033	Games,toys and hobbies	cp0931 Games, toys and hobbies
1171034	Films & oth.photographic supplies	
1171035	Flowers,plants,pets & rel.products	cp0933 Gardens, plants and flowers
		cp0934/5 Pets, veterinary services, etc
1171041	Parts & acces.for repairs recr.goods	cp0915 Repair of audio-visual, photographic equipment
1172011	Entertainment, sport, recreation, culture	cp092 Other major durables for recreation and culture
		cp0941 Recreational and sporting services
1172023	Radio-, TV-licence and rental	
1172024	Photographic & other services nec.	
1173011	Books	cp0951 Books
1173012	Newspapers,magazines etc.	cp0952 Newspapers and periodicals
		cp0953/4 Miscellaneous printed matter; stationery, etc
1174011	Fees: vocat.training,adult educ. etc.	cp0942 Cultural services
		cp10 Education
1174021	Compensation of employees	
1174031	Intermediate consumption	
1174041	Consumption of fixed capital	
1181001	Restaurants,take-a-ways & the like	cp1111 Restaurants, cafés and the like
1181002	Pubs,bars,cafes and tearooms	
1181003	Staff canteens	cp1112 Canteens
1181004	Hotels and other lodging places	cp112 Accommodation services
1182001	Services of hairdressers etc.	cp1211 Hairdressing salons and personal grooming
1182002	Durable toilet articles and repair	cp1212/3 Electrical appliances for personal care; etc
1182003	Non-durable toilet articles	
1182004	Jewellery,watches and their repair	cp1231 Jewellery, clocks and watches
1182005	Travel goods and baggage items	cp096 Package holidays
1182006	Other personal goods n.e.c.	cp1232 Other personal effects
1182007	Writing,drawing equipment & supplies	
1182008	Social security and welfare services	cp124 Social protection
1182010	Charges for financial services nec.	cp125 Insurance
		cp126 Financial services n.e.c.
1182011	Fees for other services nec.	cp127 Other services n.e.c.

TABLE 2. PRICE INDEXES FOR THE EUROPEAN UNION (1995-2000) (UK96=1)

	MST	MTFG	TCG	SCG	GM(TFGG)	M(EKS)	M(GK)	Max/Min
B00	57.09	57.15	56.75	56.37	56.85	56.67	55.62	1.03
Dk00	14.80	14.38	14.47	14.63	14.47	14.55	14.04	1.05
Ge00	3.26	3.21	3.19	3.19	3.19	3.20	3.17	1.03
Sp00	222.72	220.39	218.02	220.14	218.47	219.86	218.24	1.02
Fr00	11.04	11.05	10.91	10.87	10.91	10.90	10.77	1.03
Ir00	1.26	1.26	1.23	1.22	1.23	1.22	1.26	1.03
It00	2825.08	2776.63	2789.64	2789.19	2785.33	2790.75	2789.21	1.02
L00	64.13	63.18	62.94	62.70	63.06	62.97	60.84	1.05
N00	3.18	3.18	3.22	3.21	3.22	3.21	3.22	1.01
A00	23.87	23.53	23.73	23.89	23.72	23.83	23.60	1.02
P00	242.41	240.32	237.44	234.90	237.64	236.00	234.79	1.03
Fi00	10.96	10.78	10.70	10.75	10.71	10.74	10.54	1.04
Sw00	17.16	16.84	16.84	16.96	16.80	16.87	16.08	1.07
UK00	1.05	1.05	1.05	1.05	1.05	1.04	1.04	1.01
B99	55.78	55.84	55.50	55.70	55.60	55.74	54.81	1.02
Dk99	14.44	14.03	14.11	14.12	14.12	14.15	13.65	1.06
Ge99	3.20	3.15	3.14	3.13	3.13	3.14	3.11	1.03
Gr99	416.78	413.40	407.08	410.04	408.55	409.94	385.82	1.08
Sp99	215.48	213.23	210.93	211.81	211.37	212.13	208.79	1.03
Fr99	10.85	10.86	10.73	10.71	10.72	10.73	10.64	1.02
Ir99	1.20	1.20	1.17	1.16	1.17	1.16	1.19	1.03
It99	2754.76	2707.17	2720.20	2711.81	2716.00	2718.74	2712.76	1.02
L99	62.26	61.33	60.84	61.09	60.97	61.14	60.48	1.03
N99	3.11	3.11	3.15	3.15	3.15	3.15	3.18	1.02
A99	23.44	23.11	23.31	23.29	23.30	23.36	23.26	1.01
P99	236.04	233.40	231.19	231.60	231.40	231.69	230.83	1.02
Fi99	10.67	10.49	10.41	10.43	10.42	10.44	10.19	1.05
Sw99	16.96	16.65	16.65	16.56	16.61	16.59	15.84	1.07
UK99	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.00
B98	55.10	55.19	54.91	55.05	54.91	55.04	54.04	1.02
Dk98	14.19	13.78	13.88	13.90	13.88	13.90	13.44	1.06
Ge98	3.18	3.13	3.12	3.12	3.12	3.12	3.09	1.03
Gr98	407.28	403.97	398.24	399.81	398.24	399.82	375.31	1.09
Sp98	210.70	208.50	206.40	206.91	206.40	207.31	203.64	1.03
Fr98	10.79	10.80	10.67	10.66	10.67	10.66	10.51	1.03
Ir98	1.17	1.17	1.14	1.14	1.14	1.14	1.16	1.03
It98	2710.41	2663.92	2676.75	2670.65	2676.75	2676.43	2682.13	1.02
L98	61.60	60.10	60.23	60.34	60.23	60.40	59.83	1.03
N98	3.05	3.05	3.09	3.08	3.09	3.09	3.12	1.02
A98	23.32	22.97	23.19	23.20	23.19	23.24	23.16	1.02
P98	231.28	228.70	226.54	227.31	226.54	227.51	225.93	1.02
Fi98	10.53	10.35	10.28	10.28	10.28	10.30	10.05	1.05
Sw98	16.87	16.56	16.56	16.51	16.56	16.54	15.84	1.07
UK98	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.00
B97	54.65	54.72	54.44	54.47	54.44	54.49	53.60	1.02
Dk97	14.05	13.64	13.74	13.73	13.74	13.76	13.30	1.06
Ge97	3.16	3.12	3.10	3.10	3.10	3.10	3.07	1.03
Gr97	389.83	386.67	381.18	381.75	381.18	381.79	360.27	1.08
Sp97	207.24	205.08	203.01	203.52	203.01	203.73	200.31	1.03
Fr97	10.72	10.73	10.60	10.59	10.60	10.59	10.45	1.03

TABLE 2. PRICE INDEXES FOR THE EUROPEAN UNION (1995-2000) (UK96=1)

	MST	MTFG	TCG	SCG	GM(TFGG)	M(EKS)	M(GK)	Max/Min
Ir97	1.15	1.13	1.12	1.12	1.12	1.12	1.14	1.03
It97	2658.62	2609.82	2625.61	2623.65	2625.61	2625.42	2630.49	1.02
L97	61.05	59.56	59.69	59.75	59.69	59.81	59.35	1.03
N97	3.00	3.00	3.03	3.03	3.03	3.03	3.06	1.02
A97	23.13	22.80	23.01	23.02	23.01	23.05	22.95	1.01
P97	226.61	223.75	221.96	222.38	221.96	222.47	220.96	1.03
Fi97	10.41	10.22	10.15	10.15	10.15	10.16	9.91	1.05
Sw97	16.72	16.42	16.41	16.38	16.41	16.40	15.72	1.06
UK97	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.00
B96	53.85	53.91	53.64	53.64	53.64	53.68	52.80	1.02
Dk96	13.81	13.41	13.50	13.50	13.50	13.52	13.08	1.06
Ge96	3.12	3.07	3.05	3.05	3.05	3.05	3.02	1.03
Gr96	370.31	367.30	362.09	362.09	362.09	362.15	341.23	1.09
Sp96	203.29	201.46	199.47	199.47	199.47	199.75	196.51	1.03
Fr96	10.59	10.60	10.47	10.47	10.47	10.47	10.32	1.03
Ir96	1.13	1.11	1.11	1.11	1.11	1.11	1.12	1.02
It96	2609.11	2600.87	2576.71	2576.71	2576.71	2577.65	2580.09	1.01
L96	60.22	58.75	58.88	58.88	58.88	59.00	58.58	1.03
N96	2.95	2.94	2.98	2.98	2.98	2.98	3.01	1.02
A96	22.87	22.54	22.75	22.75	22.75	22.78	22.69	1.01
P96	222.47	219.66	217.91	217.91	217.91	218.06	216.66	1.03
Fi96	10.29	10.10	10.03	10.03	10.03	10.05	9.80	1.05
Sw96	16.49	16.28	16.13	16.13	16.13	16.15	15.42	1.07
UK96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
B95	52.90	52.96	52.69	52.57	52.69	52.72	51.83	1.02
Ge95	3.08	3.03	3.02	3.01	3.02	3.02	2.99	1.03
Gr95	343.05	340.26	335.43	337.71	335.43	336.99	316.37	1.08
Sp95	196.24	194.48	192.55	193.02	192.55	193.01	189.56	1.04
Ir95	1.10	1.09	1.08	1.08	1.08	1.08	1.09	1.02
It95	2507.24	2499.32	2476.11	2480.59	2476.11	2479.07	2479.07	1.01
N95	2.90	2.90	2.94	2.92	2.94	2.94	2.96	1.02
P95	216.06	213.33	211.63	211.73	211.63	212.19	210.45	1.03
Fi95	10.18	9.99	9.92	9.91	9.92	9.94	9.67	1.05
Sw95	16.42	16.14	15.99	16.02	15.99	16.06	15.34	1.07

TABLE 3. SIMILARITY INDEXES (L_{ab})

	MST	MTFG	TCG	SCG	GM(TFGG)	M(EKS)	M(GK)
MST	0.000	1.120	1.649	1.603	1.641	1.544	3.123
MTFG	1.120	0.000	0.814	0.821	0.798	0.788	2.184
TCG	1.649	0.814	0.000	0.223	0.039	0.206	1.688
SCG	1.603	0.821	0.223	0.000	0.205	0.148	1.781
GM(TFGG)	1.641	0.798	0.039	0.205	0.000	0.200	1.698
M(EKS)	1.544	0.788	0.206	0.148	0.200	0.000	1.830
M(GK)	3.123	2.184	1.688	1.781	1.698	1.830	0.000

TABLE 4. PRICE LEVELS Z_{kt}/Z_{bk} FOR THE EUROPEAN UNION (1995-2000) (Gexx = 1)

	MST		MTFG		TCG		SCG		GM(TFGG)		M(EKS)		M(GK)
Sw00	1.219	Sw00	1.215	Sw00	1.223	Sw00	1.231	Sw00	1.220	Sw00	1.221	Sw00	1.174
Dk00	1.192	Dk00	1.176	Dk00	1.191	Dk00	1.204	Dk00	1.191	Dk00	1.193	Dk00	1.161
Fi00	1.107	Fi00	1.106	Fi00	1.104	Fi00	1.109	Fi00	1.105	Fi00	1.105	Fi00	1.092
A00	1.041	UK00	1.054	UK00	1.060	A00	1.065	UK00	1.060	A00	1.058	A00	1.057
UK00	1.037	A00	1.042	A00	1.058	UK00	1.060	A00	1.057	UK00	1.050	UK00	1.054
Fr00	1.010	Fr00	1.027	Fr00	1.020	Fr00	1.017	Fr00	1.020	Fr00	1.016	Fr00	1.012
Ge00	1.000	Ge00	1.000	Ge00	1.000	Ge00	1.000	Ge00	1.000	Ge00	1.000	Ge00	1.000
Ir00	0.959	Ir00	0.974	L00	0.957	L00	0.953	L00	0.959	L00	0.954	Ir00	0.983
L00	0.954	L00	0.955	Ir00	0.957	Ir00	0.949	Ir00	0.957	Ir00	0.949	L00	0.929
It00	0.876	N00	0.880	N00	0.896	N00	0.894	N00	0.896	N00	0.891	N00	0.900
N00	0.866	It00	0.874	It00	0.884	It00	0.884	It00	0.882	It00	0.881	It00	0.888
B00	0.849	B00	0.863	B00	0.863	B00	0.857	B00	0.864	B00	0.859	B00	0.850
Sp00	0.803	Sp00	0.807	Sp00	0.804	Sp00	0.811	Sp00	0.805	Sp00	0.808	Sp00	0.808
P00	0.726	P00	0.731	P00	0.726	P00	0.719	P00	0.727	P00	0.720	P00	0.722

	MST		MTFG		TCG		SCG		GM(TFGG)		M(EKS)		M(GK)
Dk99	1.188	Sw99	1.174	Dk99	1.183	Dk99	1.187	Dk99	1.187	Dk99	1.186	Dk99	1.155
Sw99	1.177	Dk99	1.172	Sw99	1.178	Sw99	1.175	Sw99	1.179	Sw99	1.174	Sw99	1.131
Fi99	1.097	Fi99	1.096	Fi99	1.091	Fi99	1.097	Fi99	1.096	Fi99	1.094	Fi99	1.078
A99	1.042	A99	1.043	A99	1.056	A99	1.058	A99	1.059	A99	1.058	A99	1.063
Fr99	1.012	Fr99	1.029	Fr99	1.020	Fr99	1.021	Fr99	1.022	Fr99	1.019	Fr99	1.020
Ge99	1.000	Ge99	1.000	Ge99	1.000	Ge99	1.000	Ge99	1.000	Ge99	1.000	Ge99	1.000
UK99	0.970	UK99	0.986	UK99	0.989	UK99	0.992	UK99	0.992	UK99	0.985	UK99	0.995
L99	0.944	Ir99	0.944	L99	0.940	L99	0.947	L99	0.945	L99	0.945	Ir99	0.951
Ir99	0.930	L99	0.944	Ir99	0.924	Ir99	0.919	Ir99	0.927	Ir99	0.921	L99	0.943
It99	0.870	N99	0.878	N99	0.892	N99	0.895	N99	0.895	N99	0.891	N99	0.906
N99	0.864	It99	0.869	It99	0.875	It99	0.876	It99	0.877	It99	0.875	It99	0.881
B99	0.846	B99	0.860	B99	0.857	B99	0.863	B99	0.862	B99	0.861	B99	0.855
Sp99	0.792	Sp99	0.796	Sp99	0.790	Sp99	0.796	Sp99	0.794	Sp99	0.795	Sp99	0.789
Gr99	0.782	Gr99	0.788	Gr99	0.779	Gr99	0.787	Gr99	0.784	Gr99	0.784	Gr99	0.745
P99	0.720	P99	0.723	P99	0.719	P99	0.722	P99	0.722	P99	0.720	P99	0.724

TABLE 4. PRICE LEVELS Z_{kt}/Z_{bk} FOR THE EUROPEAN UNION (1995-2000) (Gexx = 1)

	MST		**MTFG**		**TCG**		**SCG**		**GM(TFGG)**		**M(EKS)**		**M(GK)**
Sw98	1.174	Sw98	1.171	Sw98	1.174	Sw98	1.171	Sw98	1.174	Sw98	1.174	Dk98	1.142
Dk98	1.172	Dk98	1.156	Dk98	1.168	Dk98	1.170	Dk98	1.168	Dk98	1.170	Sw98	1.135
Fi98	1.090	Fi98	1.089	Fi98	1.085	Fi98	1.085	Fi98	1.085	Fi98	1.087	Fi98	1.071
A98	1.042	A98	1.043	A98	1.056	A98	1.057	A98	1.056	A98	1.060	A98	1.066
Fr98	1.012	Fr98	1.029	Fr98	1.020	Fr98	1.019	Fr98	1.020	Fr98	1.020	Fr98	1.015
Ge98	1.000	Ge98	1.000	Ge98	1.000	Ge98	1.000	Ge98	1.000	Ge98	1.000	Ge98	1.000
UK98	0.946	UK98	0.961	UK98	0.964	UK98	0.964	UK98	0.964	UK98	0.964	UK98	0.977
L98	0.939	Ir98	0.938	L98	0.936	L98	0.937	L98	0.936	L98	0.939	Ir98	0.946
Ir98	0.923	L98	0.931	Ir98	0.917	Ir98	0.917	Ir98	0.917	Ir98	0.916	L98	0.939
It98	0.864	N98	0.865	N98	0.879	N98	0.876	N98	0.879	N98	0.878	N98	0.895
N98	0.852	It98	0.862	It98	0.869	It98	0.867	It98	0.869	It98	0.870	It98	0.880
B98	0.840	B98	0.855	B98	0.853	B98	0.855	B98	0.853	B98	0.856	B98	0.848
Sp98	0.780	Sp98	0.784	Sp98	0.779	Sp98	0.781	Sp98	0.779	Sp98	0.783	Sp98	0.777
Gr98	0.762	Gr98	0.768	Gr98	0.760	Gr98	0.763	Gr98	0.760	Gr98	0.763	Gr98	0.724
P98	0.710	P98	0.714	P98	0.709	P98	0.712	P98	0.709	P98	0.713	P98	0.715

	MST		**MTFG**		**TCG**		**SCG**		**GM(TFGG)**		**M(EKS)**		**M(GK)**
Sw97	1.201	Sw97	1.194	Sw97	1.201	Sw97	1.199	Sw97	1.201	Sw97	1.202	Sw97	1.163
Dk97	1.166	Dk97	1.147	Dk97	1.163	Dk97	1.162	Dk97	1.163	Dk97	1.166	Dk97	1.138
Fi97	1.100	Fi97	1.094	Fi97	1.093	Fi97	1.093	Fi97	1.093	Fi97	1.095	Fi97	1.079
A97	1.039	A97	1.037	A97	1.054	A97	1.054	A97	1.054	A97	1.057	A97	1.063
Fr97	1.007	Fr97	1.021	Fr97	1.015	Fr97	1.014	Fr97	1.015	Fr97	1.016	Fr97	1.012
Ge97	1.000	Ge97	1.000	Ge97	1.000	Ge97	1.000	Ge97	1.000	Ge97	1.000	Ge97	1.000
Ir97	0.955	Ir97	0.950	Ir97	0.948	Ir97	0.948	Ir97	0.948	Ir97	0.953	Ir97	0.977
L97	0.936	UK97	0.925	L97	0.933	L97	0.933	L97	0.933	L97	0.936	UK97	0.943
UK97	0.914	L97	0.925	UK97	0.931	UK97	0.931	UK97	0.931	UK97	0.932	L97	0.937
It97	0.856	N97	0.853	N97	0.867	N97	0.867	N97	0.867	N97	0.870	N97	0.886
N97	0.843	It97	0.851	It97	0.862	It97	0.861	It97	0.862	It97	0.863	It97	0.873
B97	0.838	B97	0.849	B97	0.851	B97	0.851	B97	0.851	B97	0.853	B97	0.847
Gr97	0.783	Gr97	0.786	Gr97	0.780	Gr97	0.781	Gr97	0.780	Gr97	0.783	Sp97	0.773
Sp97	0.776	Sp97	0.778	Sp97	0.775	Sp97	0.777	Sp97	0.775	Sp97	0.779	Gr97	0.745
P97	0.709	P97	0.709	P97	0.708	P97	0.709	P97	0.708	P97	0.710	P97	0.712

TABLE 4. PRICE LEVELS Z_{kt}/Z_{bk} FOR THE EUROPEAN UNION (1995-2000) (Gexx = 1)

	MST		MTFG		TCG		SCG		GM(TFGG)		M(EKS)		M(GK)
Sw96	1.188	Sw96	1.192	Sw96	1.189	Sw96	1.189	Sw96	1.189	Sw96	1.186	Sw96	1.144
Dk96	1.150	Dk96	1.135	Dk96	1.150	Dk96	1.150	Dk96	1.150	Dk96	1.149	Dk96	1.122
Fi96	1.082	Fi96	1.079	Fi96	1.079	Fi96	1.079	Fi96	1.079	Fi96	1.077	A96	1.066
A96	1.043	A96	1.045	A96	1.062	A96	1.062	A96	1.062	A96	1.060	Fi96	1.062
Ge96	1.000	Fr96	1.017	Fr96	1.011	Fr96	1.011	Fr96	1.011	Fr96	1.008	Fr96	1.004
Fr96	1.000	Ge96	1.000	Ge96	1.000	Ge96	1.000	Ge96	1.000	Ge96	1.000	Ge96	1.000
L96	0.939	L96	0.931	L96	0.940	L96	0.940	L96	0.940	L96	0.939	L96	0.941
Ir96	0.872	Ir96	0.870	Ir96	0.876	Ir96	0.876	Ir96	0.876	Ir96	0.872	Ir96	0.892
N96	0.844	N96	0.855	N96	0.872	N96	0.872	N96	0.872	N96	0.871	N96	0.887
B96	0.840	B96	0.855	B96	0.856	B96	0.856	B96	0.856	B96	0.854	B96	0.849
It96	0.817	It96	0.827	It96	0.825	It96	0.825	It96	0.825	It96	0.823	It96	0.832
Sp96	0.775	Sp96	0.781	Sp96	0.778	Sp96	0.778	Sp96	0.778	Sp96	0.777	UK96	0.777
UK96	0.754	UK96	0.767	UK96	0.772	UK96	0.772	UK96	0.772	UK96	0.769	Sp96	0.772
Gr96	0.743	Gr96	0.749	Gr96	0.743	Gr96	0.743	Gr96	0.743	Gr96	0.741	Gr96	0.705
P96	0.697	P96	0.699	P96	0.698	P96	0.698	P96	0.698	P96	0.696	P96	0.699
	MST		**MTFG**		**TCG**		**SCG**		**GM(TFGG)**		**M(EKS)**		**M(GK)**
Fi95	1.085	Fi95	1.082	Fi95	1.078	Fi95	1.081	Fi95	1.078	Fi95	1.081	Fi95	1.063
Sw95	1.072	Sw95	1.071	Sw95	1.064	Sw95	1.070	Sw95	1.064	Sw95	1.069	Sw95	1.032
Ge95	1.000	Ge95	1.000	Ge95	1.000	Ge95	1.000	Ge95	1.000	Ge95	1.000	Ge95	1.000
N95	0.842	N95	0.856	N95	0.871	N95	0.868	N95	0.871	N95	0.869	N95	0.885
B95	0.835	B95	0.850	B95	0.849	B95	0.850	B95	0.849	B95	0.849	B95	0.844
Ir95	0.822	Ir95	0.828	Ir95	0.823	Ir95	0.826	Ir95	0.823	Ir95	0.824	Ir95	0.843
Sp95	0.733	Sp95	0.738	Sp95	0.733	Sp95	0.737	Sp95	0.733	Sp95	0.735	It95	0.731
It95	0.717	It95	0.726	It95	0.722	It95	0.725	It95	0.722	It95	0.722	Sp95	0.730
Gr95	0.689	Gr95	0.695	Gr95	0.687	Gr95	0.694	Gr95	0.687	Gr95	0.691	P95	0.669
P95	0.666	P95	0.668	P95	0.665	P95	0.667	P95	0.665	P95	0.667	Gr95	0.656

TABLE 5. PRICE LEVEL SIMILARITY INDEXES (I_t)

	MST	MTFG	TCG	SCG	GM(TFGG)	M(EKS)	M(GK)
Including Greece							
1999	0.1485	0.1446	0.1480	0.1462	0.1471	0.1467	0.1444
1998	0.1524	0.1484	0.1517	0.1506	0.1517	0.1506	0.1498
1997	0.1544	0.1504	0.1530	0.1521	0.1530	0.1524	0.1500
1996	0.1673	0.1628	0.1647	0.1647	0.1647	0.1650	0.1614

	MST	MTFG	TCG	SCG	GM(TFGG)	M(EKS)	M(GK)
Excluding Greece							
2000	0.1480	0.1440	0.1466	0.1506	0.1460	0.1479	0.1395
1999	0.1449	0.1409	0.1434	0.1422	0.1427	0.1426	0.1341
1998	0.1475	0.1433	0.1458	0.1449	0.1458	0.1448	0.1374
1997	0.1523	0.1483	0.1500	0.1491	0.1500	0.1494	0.1417
1996	0.1642	0.1596	0.1605	0.1605	0.1605	0.1608	0.1514

TABLE 6. SIMILARITY OF RELATIVE PRICES G(S_{jk})

	Including Greece	Excluding Greece
2000	N/A	0.3172
1999	0.3165	0.3118
1998	0.3125	0.3089
1997	0.3055	0.3024
1996	0.3029	0.2997

TABLE 7. PRICE LEVEL SIMILARITY INDEXES (I_t) FOR TRADED AND NONTRADED AGGREGATES

	Including Greece		Excluding Greece	
	Traded (TCG)	Non-Traded (TCG)	Traded (TCG)	Non-Traded (TCG)
2000	N/A	N/A	0.1395	0.1809
1999	0.1417	0.1810	0.1347	0.1819
1998	0.1449	0.1857	0.1364	0.1855
1997	0.1453	0.1889	0.1399	0.1909
1996	0.1505	0.2081	0.1434	0.2092

TABLE 8. SIMILARITY OF RELATIVE PRICES G(S_{jk}) FOR TRADED AND NONTRADED AGGREGATES

	Including Greece	Excluding Greece
2000	N/A	0.0429
1999	0.0445	0.0481
1998	0.0454	0.0492
1997	0.0462	0.0501
1996	0.0463	0.0494